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Douglas Fir Tussock Moth Egg Hatch and Larval Development in Relation to Phenology of Grand Fir and Douglas-fir in Northeastern Oregon

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PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
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DOUGLAS FIR TUSSOCK MOTH EGG HATCH AND LARVAL DEVELOPMENT IN RELATION TO PHENOLOGY OF GRAND FIR AND DOUGLAS-FIR IN NORTHEASTERN OREGON

Reference Abstract

Wickman, Boyd E.
1976. Douglas fir tussock moth egg hatch and larval development in relation to phenology of grand fir and Douglas-fir in northeastern Oregon. USDA For. Serv. Res. Pap. PNW-206, 14 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Bud burst, shoot elongation, egg hatch, and larval development were studied on six areas in a 1973 infestation in the Blue Mountains. Bud burst and egg hatch were found to be closely related to accumulated degree-days, and peak egg hatch occurred after all buds had burst and shoots were 50 percent or more elongated. Larval development then closely followed shoot elongation. This synchrony of host and insect phenology provides an easily observed field event for monitoring Douglas fir tussock moth development.

KEYWORDS: Douglas fir tussock moth, *Orgyia pseudotsugata*, larval development, phenology, *Abies grandis*, *Pseudotsuga menziesii*.

RESEARCH SUMMARY

Research Paper PNW-206

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Information on phenological synchrony was needed in the Blue Mountains of Oregon for two hosts of the tussock moth, grand fir and Douglas-fir, and for comparing the phenological development in two widely separated areas. Therefore, in April 1973 a study was started in the Blue Mountains on six different areas. The study sites were located at various elevations, from 3,200 feet (975 m) to 4,800 feet (1 463 m), and in both pure stands of grand fir and Douglas-fir and mixed stands. Temperature records were maintained on the plots and tree and insect development measured periodically for 3 months.

An earlier study aimed at correlating temperature with development of the Douglas fir tussock moth and white fir, its host in California, showed that bud burst and egg hatch were closely related and the synchrony of host and insect phenology provided an easily observed field event for monitoring Douglas fir tussock moth development (Wickman 1976).

The Oregon study showed that heat unit accumulation was related to elevation with the lowest plot consistently running 5 to 15 days ahead of the higher plots. Bud burst started between 244 and 268 degree-days and proceeded rapidly until 90 percent of bud burst had occurred between 340 and 444 degree-days. Bud development was similar for both tree species except on the lower elevation plot where Douglas-fir bud burst preceded grand fir bud burst by several days. Bud development occurred at slightly lower accumulated degree-days than for white fir in California where first bud burst started between 290 and 356 degree-days and 90 percent occurred between 464 and 535 degree-days.

The relationship of egg hatch to bud burst showed that first egg hatch coincided with 86- to 100-percent bud burst on grand fir and 70- to 97-percent bud burst for Douglas-fir. This is slightly more than the 63- to 86-percent bud burst recorded in California on white fir. More important, all buds had burst and shoots were 75 to 90 percent elongated by the time all larvae had dispersed from the egg masses to new foliage. Measurements and observations of egg hatch revealed that this event contained the most variation. Egg hatch was found to vary at a given location over a 6- to 14-day period.

Shoot elongation was also compared with the predominant larval instar sampled on foliage through the larval development period. In 1973, 90 percent of the shoot growth took place in 29 to 44 days from mid-May until early July. In the first and second instar 85 to 97 percent of the shoot growth had taken place and by the late instars (fourth to sixth) the shoot growth was completed. This synchrony with shoot development assured the larvae of a necessary food supply of new foliage for the early instars.

The findings of this study indicate similar phenological relationships with tussock moth egg hatch and larval development for both white fir in California and grand fir and Douglas-fir in Oregon. Phenological studies suggest that monitoring bud burst in the field is a practical and simpler phenological index than monitoring Douglas fir tussock moth egg hatch. The ability to predict when young larvae first start feeding is extremely important for timing treatment operations, sampling populations, and studying natural enemies. The synchrony of insect development with bud burst seems an obvious and useful index.

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INTRODUCTION

The Douglas fir tussock moth (*Orgyia pseudotsugata* (McD.)) is a univoltine insect which seriously defoliates Douglas-fir and true fir over much of the Western United States and Canada (Wickman et al. 1973). Each female deposits up to several hundred eggs in a single mass in late summer or early fall. The masses are most commonly found on or near foliage of the host tree where the eggs overwinter. Egg hatch occurs in late spring or early summer, and emerging larvae feed first on new foliage and then on old foliage if new foliage is depleted. This is a critical portion of the insect's life cycle. Newly hatched larvae must have new growth available for feeding, or mortality by starvation is high and there are other deleterious effects on the population (Mason and Baxter 1970, Beckwith 1976). Many people have noted that egg hatch occurs shortly after bud burst of the host trees. This synchrony assures young larvae a supply of new foliage.

The first attempt to relate the time of egg hatch to ambient air temperature was by Perkins and Dolph (1967). They noted in the 1965 Douglas fir tussock moth infestation near Burns, Oregon, that egg hatch was related to accumulated average air temperatures. They concluded that "whenever the daily average cumulative air temperature nears 50 °F, Douglas fir tussock moth eggs are likely to start hatching."

A study aimed at correlating temperature with development of the Douglas fir tussock moth and the foliage of white fir (*Abies concolor* (Gord. and Glend.) Lindl.), its host in California, was conducted in 1972 on the Eldorado National Forest near Placerville, California (Wickman 1976). There bud burst and egg hatch were closely related to accumulated degree-days, with peak egg hatch occurring when 80 to 95 percent of the buds had burst. Larval development then closely followed shoot elongation. This synchrony of host and insect phenology provided an easily observed field event for monitoring Douglas fir tussock moth development and determined the schedule for population sampling.

In 1973, life table studies of Douglas fir tussock moth in Oregon (Mason, in press) showed the need for the same kind of information on phenological synchrony obtained in California. Therefore, a study was started in April 1973 in the Blue Mountains of northeastern Oregon to see if the phenological synchrony found in California in 1972 was similar for Oregon in 1973. This would indicate whether results from phenological studies can be extrapolated from one area to another. There were some differences between the California situation and this study: (1) There are two preferred host species in northeastern Oregon, grand fir (*Abies grandis* (Dougl.) Lindl.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco); (2) Mason and I were sampling population densities at least 10 times larger than in California; (3) many of the study trees had suffered heavy defoliaton in 1972 and by spring 1973 had very sparse foliage in the upper crown. I did not know what effect this might have on bud burst and shoot growth.

A second objective was to establish, for the Blue Mountains of Oregon, a reliable system for predicting Douglas fir tussock moth development based on the easily observed phenology of host tree foliage.

METHODS

The methods were similar to those used in the California phenology study (Wickman 1976) except large trees were not sampled at midcrown with pole pruners to determine bud burst.

Location of Study Areas

Six study sites were located at various elevations and exposures:

1. Frizzel Creek--3,200-foot (975-m) elevation, eastern exposure (flat), open-grown mixed grand fir--Douglas-fir second-growth stand.

2. East Mt. Emily Road--4,000-foot (1 219-m) elevation, eastern exposure, steep slope, dense grand fir second-growth stand. (Temperature records incomplete because of thermograph malfunction and observations incomplete because of logging disruption.)

3. Meacham (U.S. Weather Service Station)--4,050-foot (1 234-m) elevation, northwestern exposure (slight draw), dense grand fir young sawtimber stand.

4. Y Ridge--4,150-foot (1 265-m) elevation, western exposure (flat), open-grown mixed Douglas-fir--grand fir second-growth stand.

5. East Mt. Emily Road--4,650-foot (1 417-m) elevation, eastern exposure, moderate slope, grand fir with some Douglas-fir old-growth stand. (Records incomplete because logging activity prevented regular access.)

6. Drumhill Ridge--4,800-foot (1 463-m) elevation, slight eastern exposure (ridgetop), open-grown mixed grand fir--Douglas-fir old-growth stand. (Temperature records incomplete because of thermograph malfunction.)

Only areas 1, 3, and 4 had complete temperature, egg hatch, and foliage measurements. The other three areas produced only partial data.

A several-acre plot composed of 10 open-grown trees 10 to 15 feet (3 to 5 m) tall was marked in each area. Each area except 2 and 3, which were all grand fir, contained five grand fir and five Douglas-fir trees.

Temperature Records

Air temperature recording stations were set up on each study plot. Each station contained a 7-day recording hygrothermograph and a maximum-minimum thermometer placed in a standard weather instrument shelter. The Meacham U.S. Weather Service Station, located 200 feet (61 m) from the study trees provided daily temperature records for that plot and a check for aberrations on other plots. A threshold temperature of 42 °F (7 °C) was used to keep this study comparable with the California measurements (Wickman 1976). The heat units were accumulated by summing daily averages. One degree of the mean daily temperature above the 42 °F threshold is known as a degree-day. Accumulated degree-days were then calculated for each plot. If degree-day calculation resulted in a negative value it was considered zero, since growth can only be arrested, not reversed.

Foliage Sampling

Each study tree had four tagged primary branches on the four cardinal sides of the midcrown. Seven days after the average daily temperature reached 42 °F one terminal bud on each branch was marked, measured, and examined at 3-day intervals. After the 14th day, buds were examined daily until first bud burst. After bud burst, the new shoot on each branch was measured to the nearest 0.25 inch (0.6 cm) every 3 days during egg hatch and dispersal of larvae off the egg masses. Additional weekly measurements were made until shoot growth was complete.

For the purposes of this study, bud burst occurred whenever individual needles were protruding from the transparent sheath encasing expanding buds and thus available to the young larvae for feeding.

Egg Mass Examinations and Larval Samples

Four egg masses per tree on five trees per plot were marked and examined every other day until first egg hatch. Through the egg hatch and dispersal period, the number of larvae resting on the egg masses was counted daily with the aid of a magnifying glass to obtain a hatch index. This was continued until all the larvae left the egg masses.

Feeding larvae were sampled from the midcrown foliage of 15 nearby trees at Y Ridge and Drumhill Ridge every 2 weeks until pupation; a standard sampling technique was used (Mason 1970). The predominant larval instar at a given sample date was then compared with average shoot growth.

RESULTS AND DISCUSSION

To demonstrate a relationship between development of the tussock moth and the phenology of its hosts, several steps were taken with the field data. Heat unit accumulation by date was compared between areas to point out elevational differences; then degree-days were compared with bud burst at each study site. Egg hatch was monitored, quantified, and related to degree-days and bud burst; and, finally, shoot elongation was compared with larval development. The following sections give the results of each of these portions of the study and discuss additional observations and problems encountered.

Degree-days and Bud Burst

Heat unit accumulation was related to elevation with the lowest plot, Frizzel Creek, consistently running 5 to 15 days ahead of the higher plots, Y Ridge and Meacham (fig. 1). Figure 1 also shows that Y Ridge and Meacham had similar heat unit accumulations. This is expected since there is only a 100-foot (30-m) elevation difference between the two localities, but the close fit indicates that the thermograph recordings, at this location at least, were comparable to a U.S. Weather Service Station with more sophisticated automated equipment. Unfortunately, two of the five field thermographs developed serious malfunctions during the season.

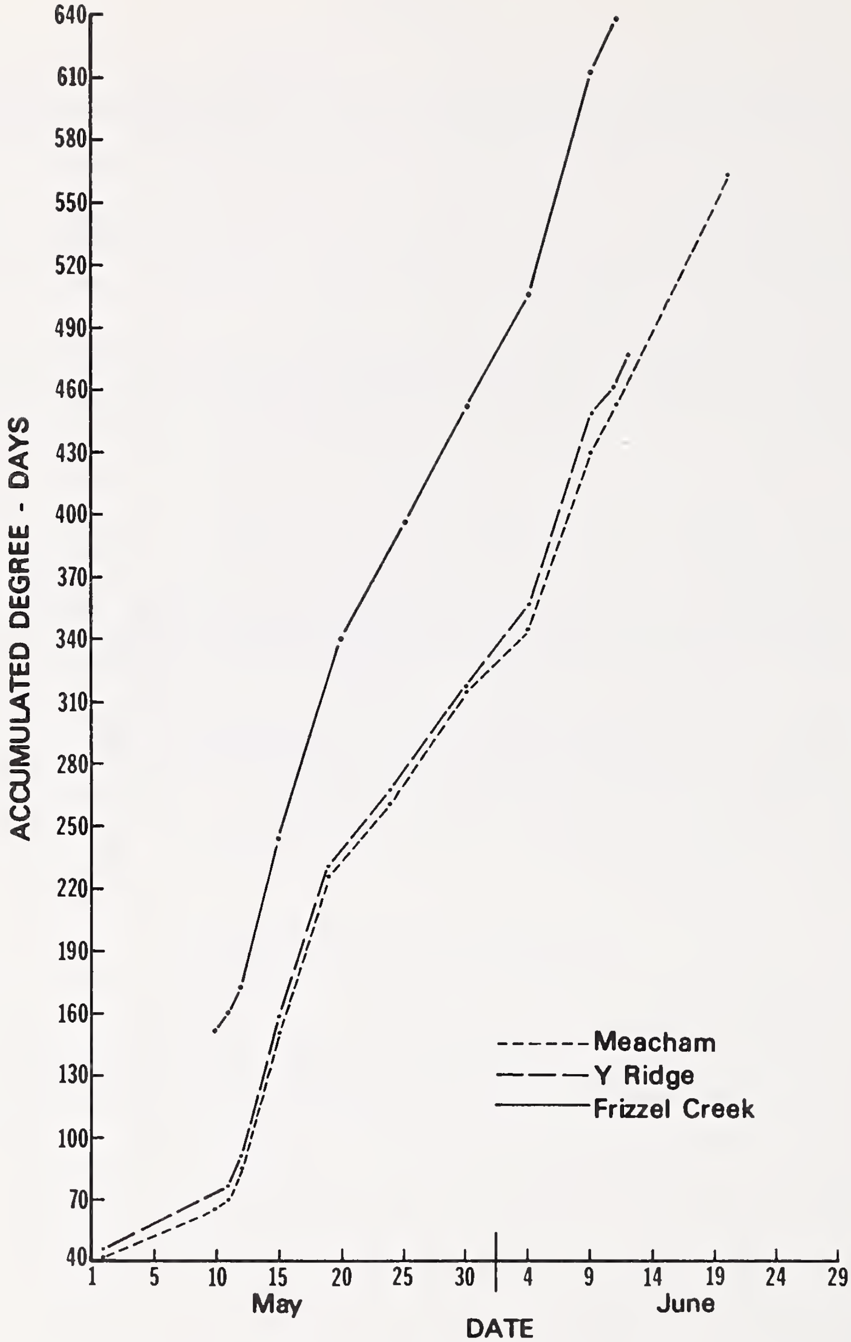

Figure 1.--Accumulated degree-days, June 1973, on phenology plots, Blue Mountains, Oregon.

Figure 2 shows bud burst by date for each of the six plot sites. Figure 2A, for grand fir, reveals a consistent pattern of development,

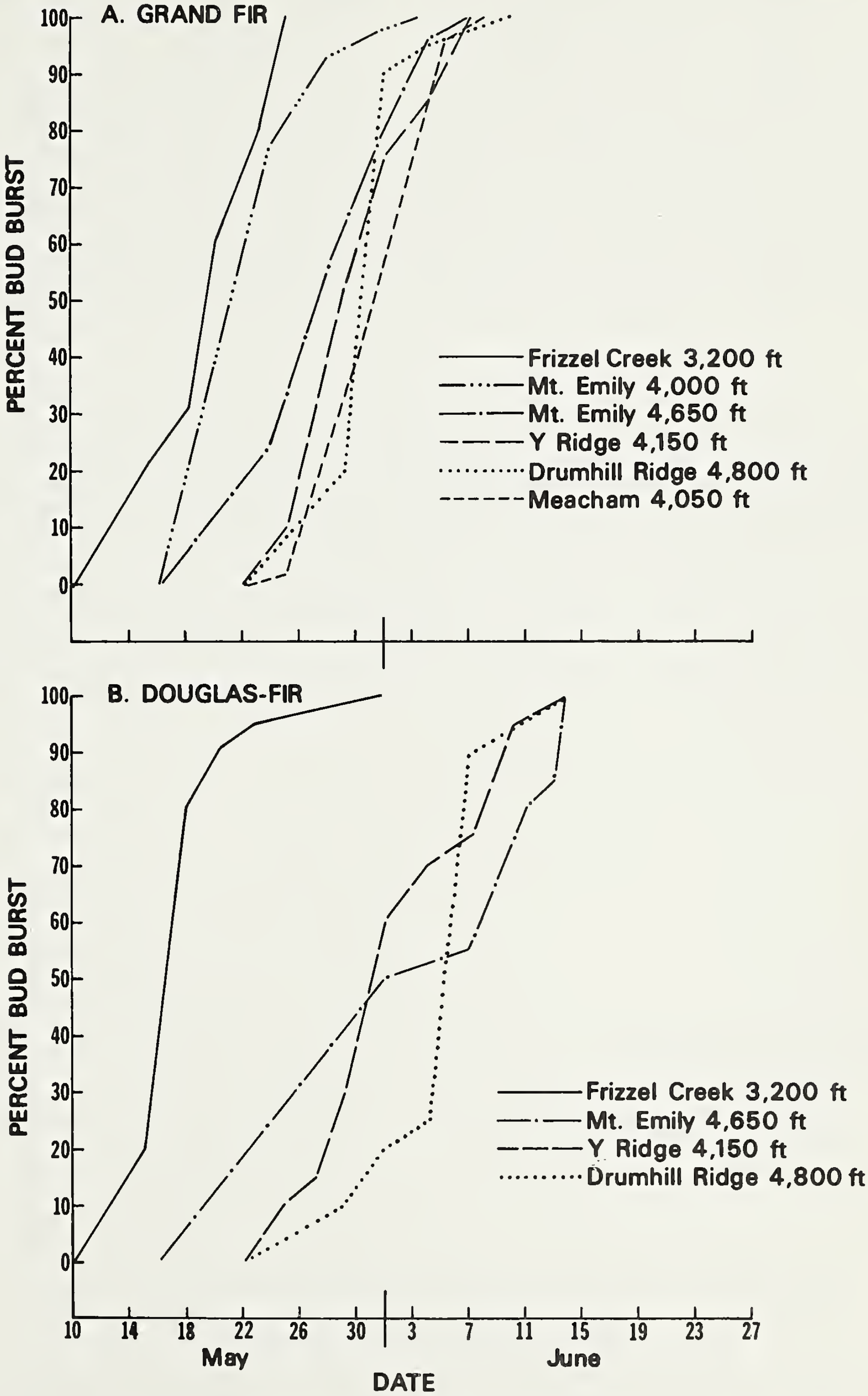

Figure 2--Percent bud burst by date and phenology plot, 1973: A, grand fir; B, Douglas-fir.

starting at the lowest elevation (Frizzel Creek, 3,200 feet (975 m)) and proceeding to the highest (Drumhill Ridge, 4,800 feet (1 463 m)). The only exception was the Meacham plot (4,050 feet (1 234 m)) where development was similar to the highest plot. This anomaly was most likely due to plot location at Meacham. The trees nearest the weather station were about 200 feet (61 m) away in a slight draw which proved cooler than the site of the U.S. Weather Service instruments. The lower temperatures at the plot were confirmed by several spot checks with a mercury thermometer. This points out the difficulty of selecting broadly representative sites for studying phenological events; care must be taken not to extrapolate temperatures to areas very distant from the study sites. Hopkin's Law (1918) regarding delay in development with increased elevation is a well-documented generalization, even in the Blue Mountains (Wagg 1958); however, exceptions do exist, usually because of effects of local physiography on heat unit development.

Figure 2B indicates an interesting characteristic of Douglas-fir bud burst noted during this study. In the lowest elevation plot at Frizzel Creek, Douglas-fir consistently flushed new foliage before grand fir. The reverse was true on all the other areas, with Douglas-fir bud burst lagging several days behind grand fir. The situation at Frizzel Creek may have been influenced by the eastern exposure slowing development of grand fir.

Bud burst often occurred first on the most open-grown trees, the upper crown of large trees, and sometimes on the south aspect of sample trees, but there was no substantial difference by aspect on the sample trees. This agrees with findings in the California study (Wickman 1976).

Percent bud burst plotted against accumulated degree-days for grand fir and Douglas-fir at Frizzel Creek, Y Ridge, and Meacham (only grand fir) is shown in figure 3. Bud burst started between 244 and 268 degree-days and proceeded rapidly until 90 percent of the bud burst had occurred between 340 and 386 degree-days (except for Douglas-fir at Y Ridge which reached the 90-percent bud burst point at 444 degree-days). Bud development occurred at lower accumulated degree-days than for white fir in California. There, first bud burst started between 290 and 356 degree-days and 90 percent occurred between 464 and 535 degree-days (Wickman 1976). Some of this difference might be explained by the effects of unseasonably warm spring weather in Oregon in 1973 versus the unseasonably cool spring in California in 1972. And since the relationship of bud development with temperature is curvilinear, the onset of bud burst increases with the rate of temperature accumulation. As California was cooler, there was a slower rate of development for the same accumulated temperature.

Degree-days, Bud Burst, and Egg Hatch

The relationship of egg hatch to accumulated degree-days and bud burst must be demonstrated to ultimately use bud burst alone as a field indicator of egg hatch. The first step is shown in figure 4; average number of larvae per egg mass (counted on the egg mass) is plotted by accumulated degree-days for Frizzel Creek, Y Ridge, and Meacham. The Y Ridge curve shows an extended period of egg hatch which I believe was

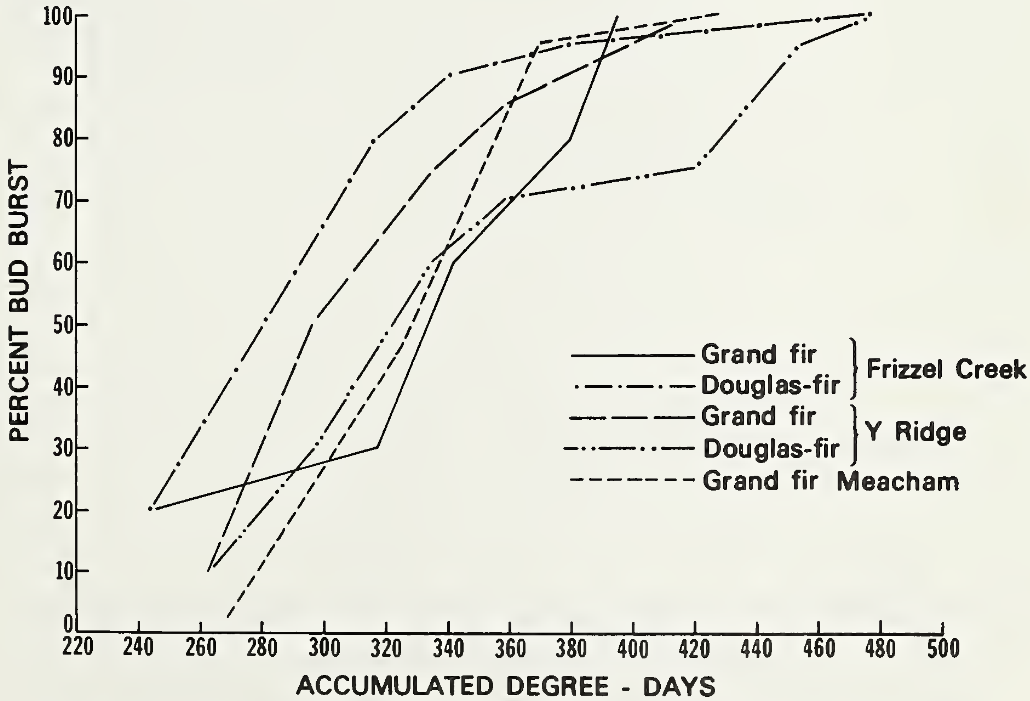

Figure 3.--Accumulated degree-days and percent bud burst by grand fir and Douglas-fir, phenology plots, 1973.

due to additional exposure of egg masses to solar radiation. Eight egg masses were located on trees in large openings and exposed to longer periods of radiation. Masses on those trees hatched several days earlier than on trees in the fringe of the stand canopy.

Comparison of figure 4 with figure 5 shows peak egg hatch occurred 4 days after first egg hatch at Frizzel Creek, 10 days after first hatch at Meacham, and one peak 3 days after first hatch and a second peak 10 days later at Y Ridge. Except for Frizzel Creek, this period is slightly longer than found in California, but the time from peak egg hatch to complete dispersal off the egg masses was shorter than in California (7 to 10 days); at Frizzel Creek it was 4 days, Meacham 5 days, and Y Ridge 2 days (for the second peak).

The accumulated degree-days plotted against percent bud burst and egg hatch are also illustrated by figure 5. These graphs point out that on our study areas in 1973, first egg hatch coincided with 86- to 100-percent bud burst on grand fir and 70- to 97-percent bud burst for Douglas-fir. This is slightly more than the 63- to 86-percent bud burst recorded in California on white fir in 1972 (Wickman 1976). More important, all buds

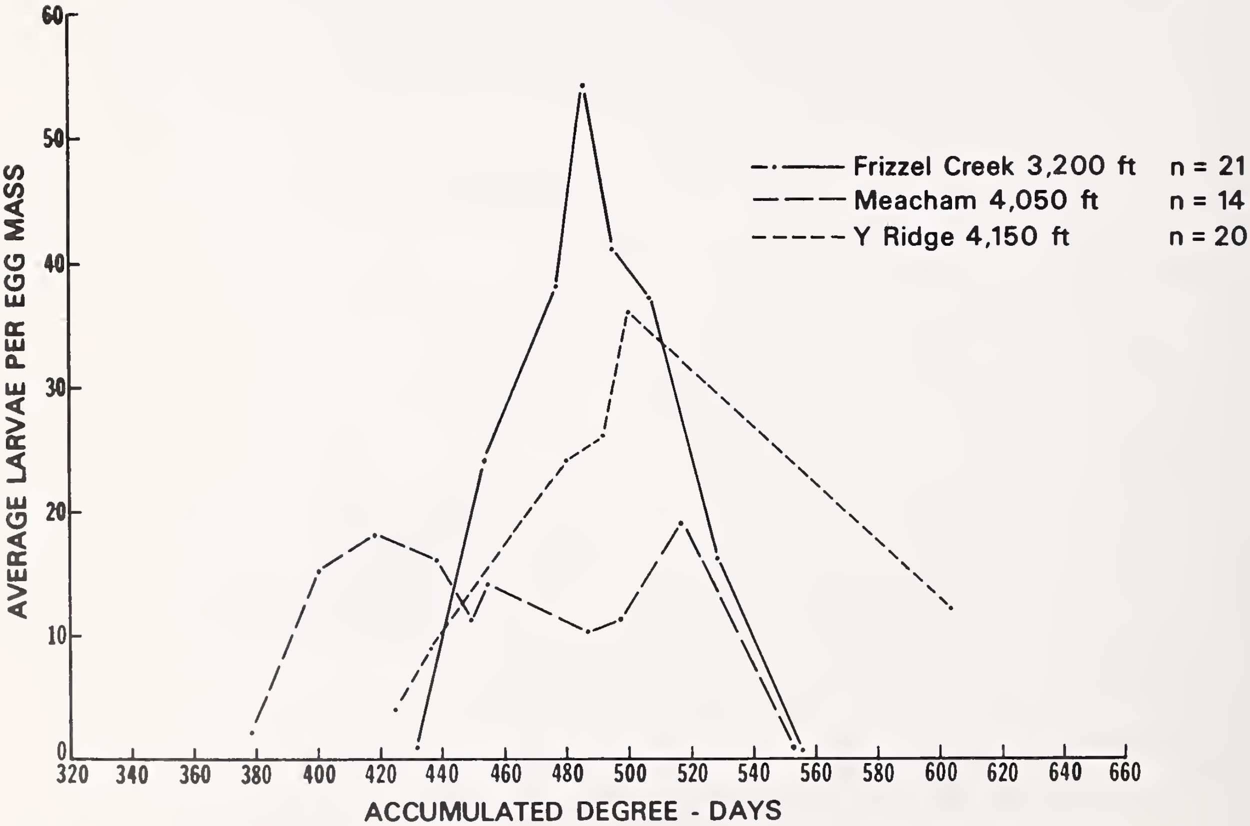

Figure 4.--Average number of larvae per egg mass (counted on the egg mass), phenology plots, 1973.

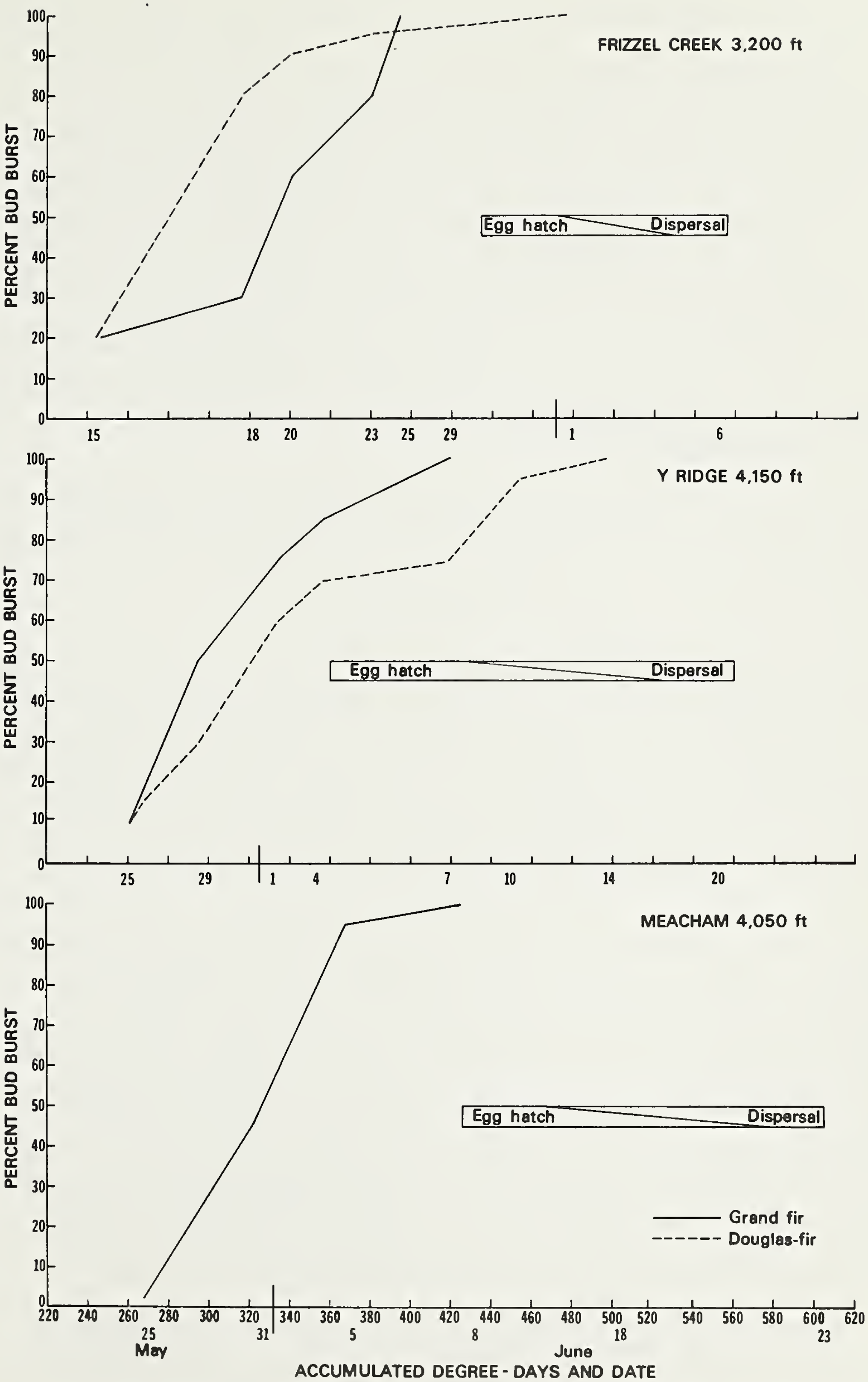

Figure 5.--Accumulated degree-days, percent bud burst, and egg hatch and dispersal for three phenology plots, 1973.

had burst and shoots were 85 to 90 percent elongated by the time all larvae had dispersed from the egg masses to new foliage and were vigorously feeding.

Measurements and observations of egg hatch revealed that this event contained the most variation. Apparently, eggs in the tops of large exposed trees hatched first (buds in the tops of these trees also burst earlier). The dispersal of larvae from these trees resulted in long silken threads, easily seen when looking toward the sun, streaming from the tops of trees. Because larvae remain on the egg masses for several days before dispersing, first egg hatch probably preceded visual evidence of silk threads in tree tops by about 3 days. Egg hatch lower in the crown (and this is where most egg masses are located in heavily defoliated trees) coincided well with hatch on tagged masses and started about the time silk was seen. Egg masses in the lower crowns of trees in dense stands with light defoliation were the last to hatch, and in several locations hatch occurred 3 to 4 days after hatch at midcrown. This means that egg hatch can occur at a given locality over a 6- to 14-day period, and, when egg masses are tagged for observation of hatch, the amount of exposure to solar radiation must be considered.

Also, in the declining phase of an outbreak some egg masses produce few or no larvae. If these egg masses are tagged for observation, they will obviously result in some miscalculations, especially when the sample size is small.

Shoot Elongation and Larval Development

Comparison of shoot elongation with the predominant larval instar sampled on foliage through the larval development period was possible for only two of the six study sites (fig. 6). The shoot growth was measured on three additional study plots not sampled for larvae and showed a similar configuration and time scale. In this 1973 study, 90 percent or more of the shoot growth took place in 29 to 44 days from mid-May until early July. This was a longer time period than in the California study (about 32 days), but there was only a 600-foot (183-m) elevation difference in California between plots compared with 1,600 feet (488 m) in Oregon.

In 1973 shoot growth was 90 percent or more complete by the second instar. In California in 1972 only 50 percent of the shoot growth had taken place during the third and fourth larval instars (Wickman 1976). In Oregon, summer 1973 was particularly warm and dry, and rapid shoot growth by the time of second instar development insured the larvae the maximum food supply possible. This, in turn, resulted in heavy feeding on almost all available new growth by the very dense larvae populations on our plots. Thus the unusually warm weather hastened shoot growth but probably also stimulated more rapid larval feeding. This heavy larval feeding in Oregon resulted in reduced total length shoot growth, and also could have ended growth earlier in the season, explaining the differences between Oregon and California. The total end of season (1973) average shoot length at Y Ridge was 1.02 inches (2.59 cm) for grand fir and 1.17 inches (2.97 cm) for Douglas-fir; at Drumhill Ridge it was 1.35 inches (3.43 cm) for grand fir and 1.40 inches (3.56 cm) for Douglas-fir.

Aspect caused no appreciable difference in shoot growth, either by development rate or total length. This is similar to the findings of Morris et al. (1956) on balsam fir in New Brunswick and Wickman (1976) on white fir in California.

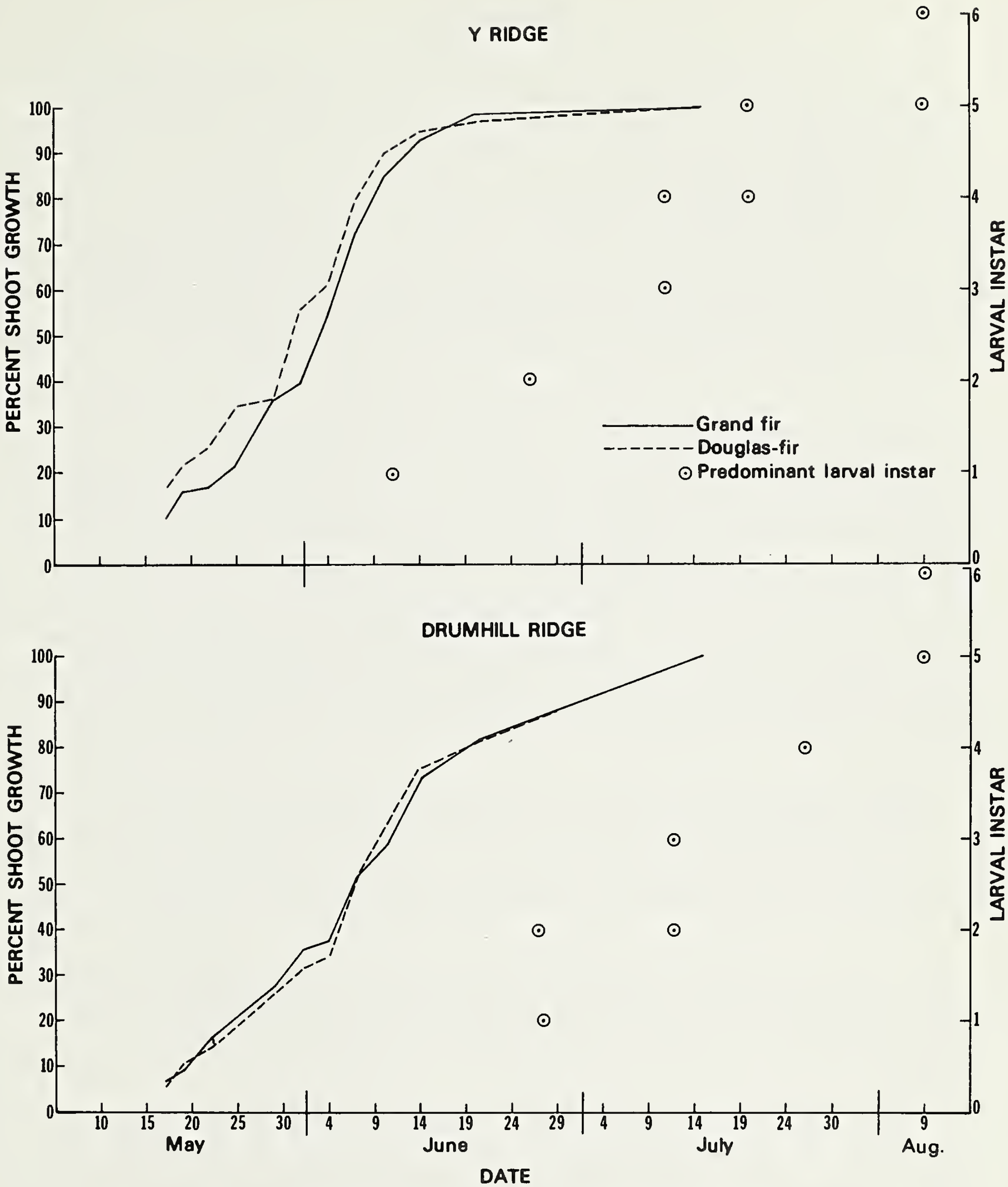

Figure 6.--Relationship of shoot growth and larval development on two phenology plots, 1973.

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